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(54) **MICRO-ELECTROMECHANICAL SYSTEM MICROPHONE**

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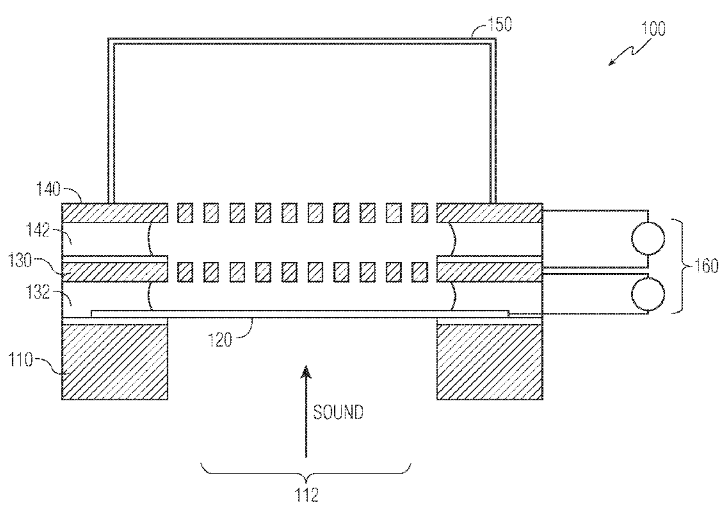
(57) **ABSTRACT**

A capacitive micro-electromechanical system (MEMS) microphone includes a semiconductor substrate having an opening that extends through the substrate. The microphone has a membrane that extends across the opening and a back-plate that extends across the opening. The membrane is configured to generate a signal in response to sound. The back-plate is separated from the membrane by an insulator and the back-plate exhibits a spring constant. The microphone further includes a back-chamber that encloses the opening to form a pressure chamber with the membrane, and a tuning structure configured to set a resonance frequency of the back-plate to a value that is substantially the same as a value of a resonance frequency of the membrane.

23 Claims, 4 Drawing Sheets



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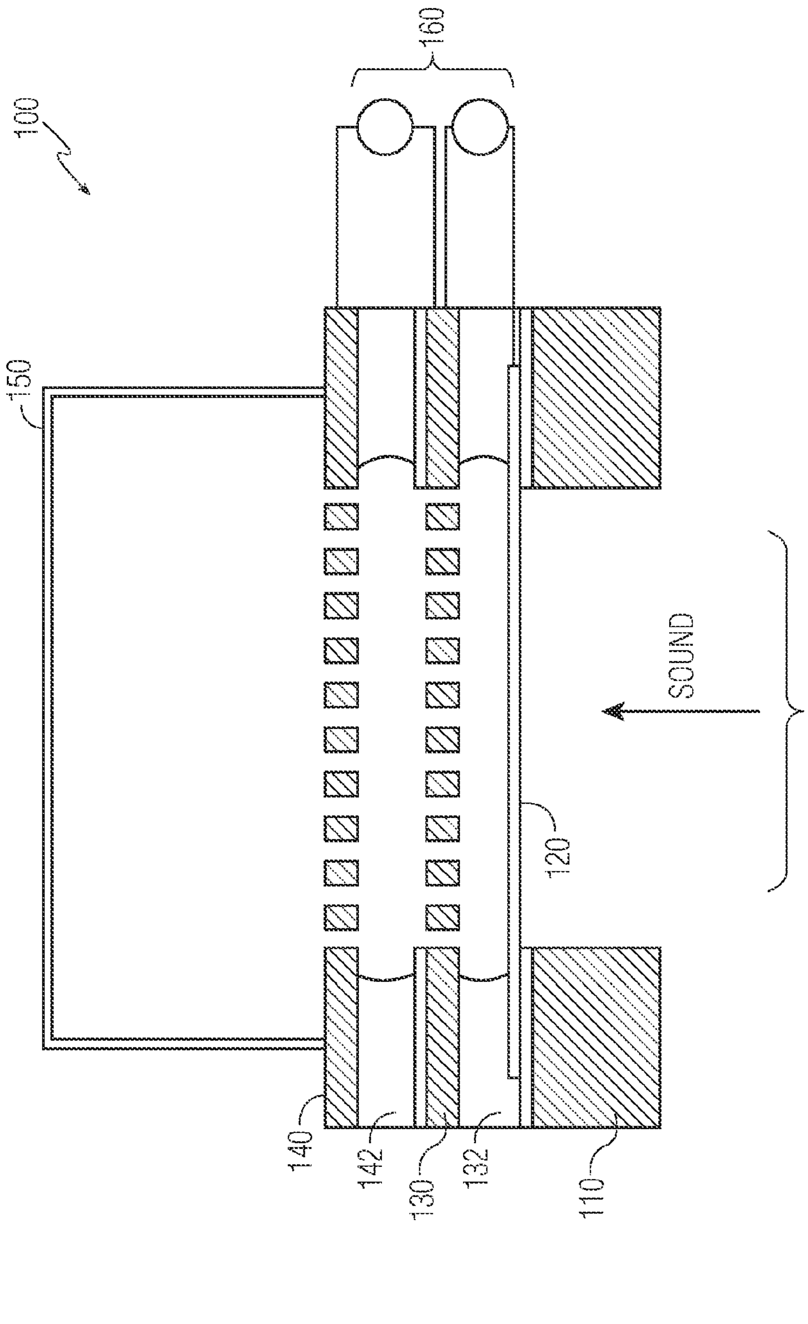

FIG. 1

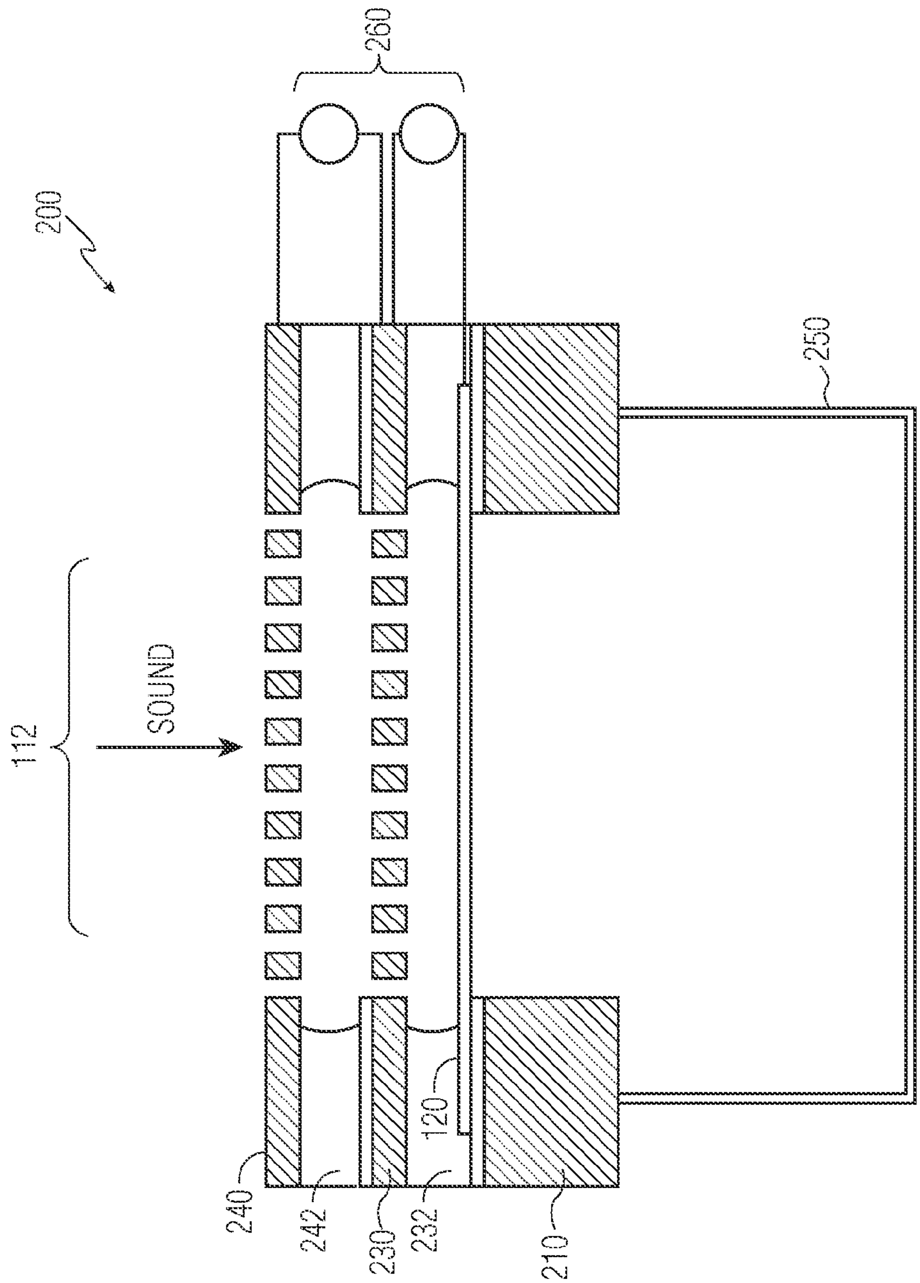

FIG. 2

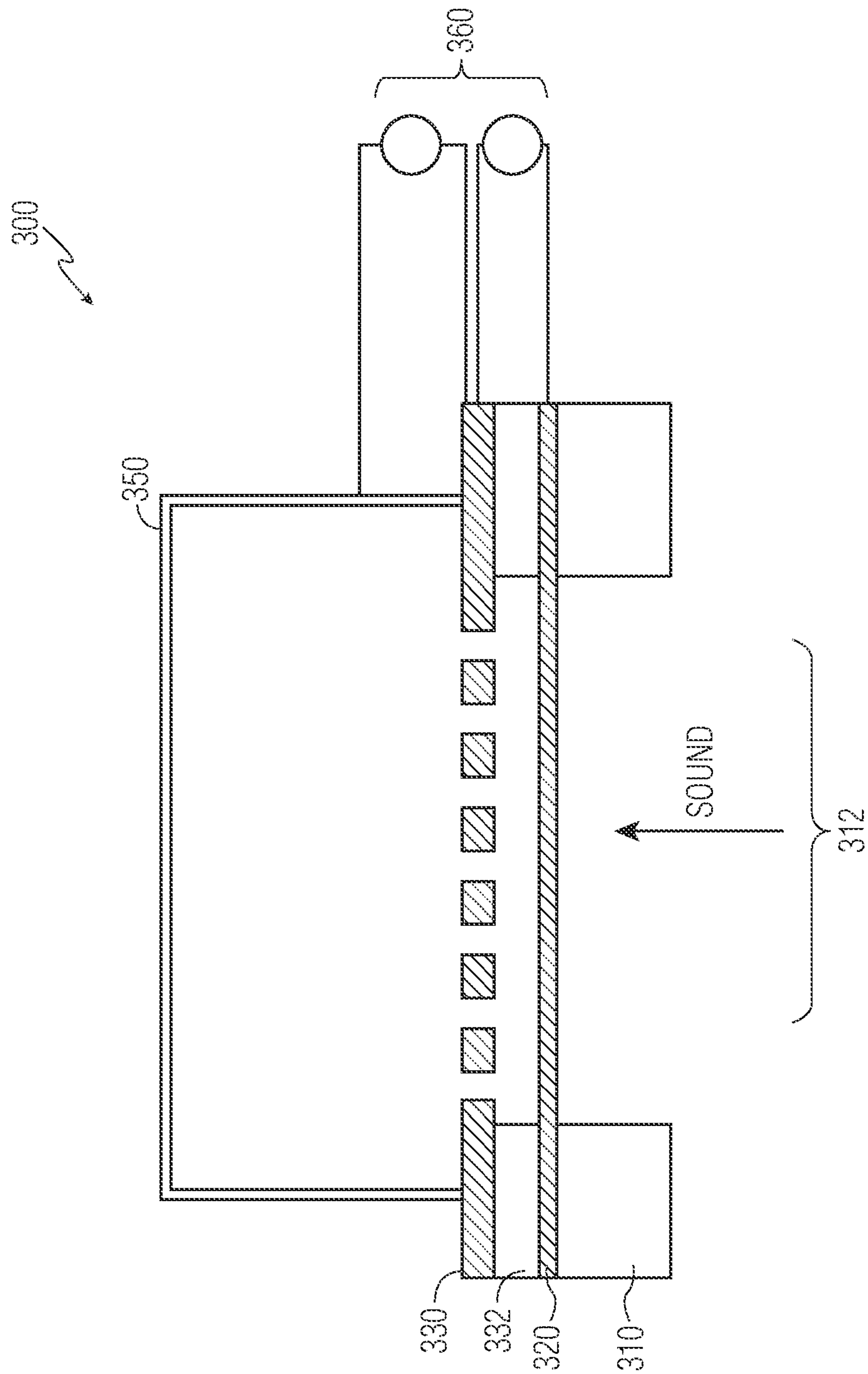

FIG. 3

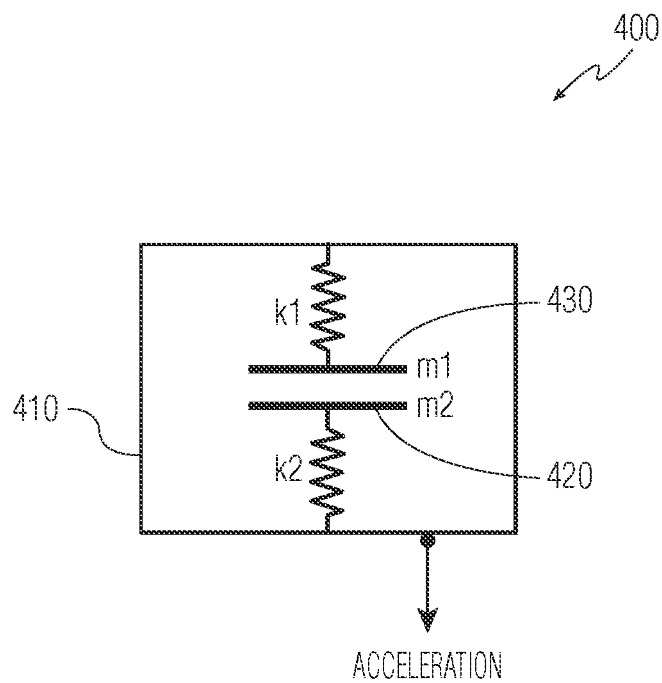

FIG. 4

MICRO-ELECTROMECHANICAL SYSTEM MICROPHONE

FIELD OF THE INVENTION

The present invention relates generally to a micro-electromechanical system (MEMS) microphone, and more specifically, to controlling the resonance frequency of the backplate of an MEMS microphone.

BACKGROUND

A micro-electromechanical system (MEMS) is a microscopic machine that is fabricated using the same types of steps (e.g., the deposition of layers of material and the selective removal of the layers of material) that are used to fabricate conventional analog and digital CMOS circuits.

One type of MEMS is a microphone. A capacitive MEMS microphone uses a membrane (or diaphragm) that vibrates in response to pressure changes (e.g., sound waves). The membrane is a thin layer of material suspended across an opening in a substrate. The microphone converts the pressure changes into electrical signals by measuring changes in the deformation of the membrane. The deformation of the membrane, in turn, leads to changes in the capacitance of the membrane (as part of a capacitive membrane/counter electrode arrangement). In operation, changes in air pressure (e.g., sound waves) cause the membrane to vibrate which, in turn, causes changes in the capacitance of the membrane that are proportional to the deformation of the membrane, and thus can be used to convert pressure waves into electrical signals.

MEMS microphones are susceptible to the influence of mechanical vibrations (e.g., structure-borne sound), such as may relate to movement of the microphone and/or the device in which the microphone is employed. These vibrations can be undesirably detected as noise, and interfere with the ability of the microphone to accurately detect sound. In addition, many approaches to mitigating noise can affect the ability of the microphone to detect sound, hindering the resolution of the microphone.

The implementation of MEMS microphones continues to be challenging, in view of the above and other issues.

SUMMARY

Consistent with an example embodiment of the present invention, a capacitive micro-electromechanical system (MEMS) microphone includes a semiconductor substrate having an opening that extends through the substrate. The microphone has a membrane that extends across the opening and a back-plate that extends across the opening. The membrane is configured to generate a signal in response to sound. The back-plate is separated from the membrane by an insulator and the back-plate exhibits a spring constant. The microphone further includes a back-chamber that encloses the opening to form a pressure chamber with the membrane, and a tuning structure configured to set a resonance frequency of the back-plate to a value that is substantially the same as a value of a resonance frequency of the membrane (e.g., to match the mechanical acceleration response of the back-plate to the mechanical acceleration response of the membrane).

According to another example embodiment of the present invention, a capacitive MEMS microphone includes a semiconductor substrate having an opening that extends through the substrate. The microphone has a pressure sensitive membrane that extends across the opening and that is configured to generate a signal in response to sound waves. The microphone also has a spring-suspended back-plate that extends across the opening. The spring-suspended back-plate is separated from the pressure sensitive membrane by a first insulator and the back-plate exhibits a spring constant. The microphone further has a tuning back-plate that extends across the opening and that is separated from the spring-suspended back-plate by a second insulator. The microphone further includes a back-chamber that encloses the opening to form a pressure chamber with the membrane, and a bias circuit configured to apply a tuning bias voltage to the tuning back-plate to set a resonance frequency of the spring-suspended back-plate (e.g., a fundamental resonance frequency) to a value that is substantially the same as a value of a resonance frequency of the membrane.

The above summary is not intended to describe each embodiment or every implementation of the present disclosure. The figures and detailed description that follow more particularly exemplify various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. **1** shows a diagram of a MEMS microphone, according to an example embodiment of the present invention;

FIG. **2** shows a diagram of a MEMS microphone, according to another example embodiment of the present invention;

FIG. **3** shows a diagram of a MEMS microphone, consistent with a further embodiment of the present invention; and

FIG. **4** shows a schematic of an MEMS microphone, according to a further example embodiment of the present invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention including aspects defined by the appended claims.

DETAILED DESCRIPTION

The present invention is believed to be applicable to a variety of different types of processes, devices and arrangements for use with MEMS microphones. While the present invention is not necessarily so limited, various aspects of the invention may be appreciated through a discussion of examples using this context.

According to an example embodiment of the present invention, a capacitive MEMS microphone includes a semiconductor substrate having an opening that extends through the substrate. A membrane extends across the opening in the substrate, with the membrane being configured to generate a signal in response to sound. A back-plate also extends across the opening in the substrate and separated from the membrane by an insulator. The back-plate exhibits a spring constant. A back-chamber encloses the opening in the substrate to form a pressure chamber with the membrane. The microphone includes a tuning structure configured to set a resonance frequency of the back-plate to a value that is substantially the same as a value of a resonance frequency of the membrane. Setting the resonance frequency of the back-plate substantially equal to the resonance frequency of the membrane (or, e.g., matching the mechanical acceleration response of the back-plate to the mechanical acceleration response of the membrane) mitigates the susceptibility of the MEMS microphone to mechanical vibrations. In one implementation, the tuning structure includes a tuning back-plate and the resonance frequency of the back-plate is set by applying a bias voltage between the back-plate and the tuning plate.

In the following discussion, various reference is made to matching or otherwise setting a resonance frequency of a back-plate relative to a membrane. In these embodiments, this approach to setting resonance frequency may involve (as an alternative or part of the same approach) setting or controlling the mechanical acceleration response of the back-plate so that it matches the mechanical acceleration response of the membrane. Accordingly, various embodiments involving resonance frequency matching may, instead and/or in addition, match mechanical acceleration responses of the back-plate and membrane.

According to another example embodiment of the present invention, a capacitive MEMS microphone includes a membrane, a flexible back-plate and a second stiffer back-plate on top of the flexible back-plate. The second stiffer back-plate is used to fine-tune the frequency matching between the back-plate and the membrane. A back-plate is always flexible because it is made from a material with a certain Young's modulus/stress and the back-plate has a certain limited thickness. The flexible back-plate is somewhat more flexible than the second stiffer back-plate, which is also somewhat flexible. A first bias voltage is applied between the membrane and the flexible back-plate. The first bias voltage affects the sensitivity of the membrane as well as the resonance frequencies of the membrane and the flexible back-plate. A second bias voltage is applied between the flexible back-plate and the stiff back-plate. The second bias voltage affects the resonance frequency of the flexible back-plate and is used to adjust the resonance frequency of the flexible back-plate without influencing the sensitivity for sound of the membrane. Thus, the second stiffer back-plate and the second bias voltage allow for tuning of the resonance frequency of the flexible back-plate in a manner that is independent of the membrane.

According to a further example embodiment of the present invention, the sensitivity of a capacitive silicon MEMS microphone is set to a desired level by reducing (e.g., minimizing) the influence of mechanical vibrations (e.g., structure-borne sound). In one implementation, such a result is achieved by giving the back-plate the same resonance frequency as the membrane, thereby making the microphone intrinsically insensitive to mechanical noise in the acoustical frequency range. The same resonance frequency refers to the back-plate and membrane having the same excursion for a certain acceleration, because both the resonance frequency and the sensitivity for accelerations of a membrane or a back-plate are given by the k/M ratio (spring constant over mass). In a specific implementation, the resonance frequency of the back-plate is set so that the resonance frequencies of the back-plate and membrane match within 10%.

According to another embodiment of the present invention, electrical tune-able frequency matching of a flexible back-plate (e.g., a spring-suspended back-plate) is performed during operation of the microphone for full body-noise suppression. The resonance frequency of the back-plate is set via electrostatic force between a tuning back-plate and the back-plate resulting from a bias voltage applied to the tuning back-plate. In one implementation, the back-plate is flexible and the tuning back-plate is a stiff back-plate that is less flexible than the back-plate.

According to another embodiment of the present invention, a capacitive MEMS includes a membrane and a back-plate that each have a different sensitivity for acceleration, which leads to a different deflection and therefore to an output signal. This effect, referred to as body noise, is suppressed by matching the resonance frequency of the back-plate to the resonance frequency of the membrane. The membrane excursion Δx relates to acceleration as indicated by equation 1:

$$\left.\begin{aligned} F &= M \cdot a \\ F &= k \cdot \Delta x \end{aligned}\right\} \Delta x = \frac{M}{k} \cdot a \tag{1}$$

The resonance frequency is given by equation 2:

$$f_{res} = \frac{1}{2\pi} \cdot \left(\sqrt{\frac{M}{k}}\right)^{-1} \tag{2}$$

which shows that the ratio M/k determines both the sensitivity and the resonance frequency. Therefore, the resonance frequencies of membrane and the back-plate have the following relationship:

$$f_{res,m} = f_{res,bp} \Rightarrow \Delta x_m = \Delta x_{bp} \Rightarrow \Delta V = 0 \tag{3}$$

In more general terms:

$$\Delta x = \Delta x_m - \Delta x_{bp} = a \cdot \left(\frac{1}{(2\pi f_{res,mem})^2} - \frac{1}{(2\pi f_{res,bp})^2}\right) = a \cdot \left(\frac{(2\pi f_{res,bp})^2 - (2\pi f_{res,mem})^2}{(2\pi f_{res,mem})^2 (2\pi f_{res,bp})^2}\right) \tag{4}$$

$$f_{res,mem} \rightarrow f_{res,bp} \Rightarrow \Delta V \downarrow \tag{5}$$

Thus, matching the resonance frequency of the back-plate to the resonance frequency of the membrane reduces body noise.

FIG. **1** shows a diagram of a capacitive MEMS microphone **100**, according to an example embodiment of the present invention. The microphone **100** includes a semiconductor substrate **110** having an opening **112** that extends through the substrate **110**. A pressure sensitive membrane **120** extends across the opening **112** in the substrate **110**. The membrane **120** is configured to generate a signal in response to sound. A perforated back-plate **130** also extends across the opening **112** in the substrate **110**. The back-plate **130** is separated from the membrane **120** by insulating material **132**. The microphone **100** further includes a perforated tuning back-plate **140** that extends across the opening **112** in the substrate **110**. The tuning back-plate **140** is separated from the back-plate **130** by insulating material **142**. A back-chamber **150** encloses the opening **112** to form a pressure chamber with the membrane **120**.

A tuning bias voltage is applied between the back-plate **130** and the tuning back-plate **140**. For example, the MEMS microphone **100** includes a bias circuit **160** that is configured to apply the tuning bias voltage. The tuning bias voltage is applied to electrically tune the resonance frequency of the back-plate **130** to match the resonance frequency of the membrane **120** and thereby suppress body noise (e.g., in accordance with equations 1-5 above).

In one implementation, electrically tuning the resonance frequency of the back-plate **130** using the tuning bias voltage decouples body nose compensation from microphone sensitivity. For example, the tuning back-plate **140** is used to give the back-plate **130** an extra spring softening without altering the sensitivity of the membrane **120**. Application of the tuning bias voltage alters the resonance frequency of the back-plate **130** via electrostatic force between the tuning back-plate **140** and the back-plate **130**.

In a further implementation, the bias circuit **160** is configured to apply a bias voltage between the membrane **120** and the back-plate **130** to set the sensitivity of the membrane. The capacitive microphone **100** has a parallel plate set-up consisting of the membrane **120** and the back-plate **130**. The membrane **120** can be considered to be in the electrical field of the membrane **130** and therefore encounters an electrical force as shown by equation 6:

$$F_{el} = \frac{q^2}{2\varepsilon_0 A} \tag{6}$$

with q being the charge on the plates, A being the surface of the plates and ϵ_0 being the permittivity of air. The charge q is determined by a bias voltage applied over the parallel plate capacitor, with q being defined by equation 7:

$$q = C \cdot V_{bias} = \frac{\varepsilon_0 A}{d_0} V_{bias}. \tag{7}$$

The combination of equations 6 and 7 results in equation 8:

$$F_{el} = \frac{\varepsilon_0 A}{2d_0(d_0 + \Delta x)} V_{bias}^2 \approx \frac{\varepsilon_0 A}{2d_0^2} V_{bias}^2 - \frac{\varepsilon_0 A}{2d_0^3} V_{bias}^2 \Delta x \tag{8}$$

with Δx being the excursion of the membrane **120** and the back-plate **130** with respect to each other. The membrane **120** is suspended by a spring constant k_{mech} and the membrane will have an additional negative spring resulting from the applied bias voltage as defined by equation 9:

$$k_{el} = -(\epsilon_0 A / 2d_o^{\,3}) V^2_{bias} \tag{9}$$

This effect is referred to as spring softening because the total spring constant k of the membrane is smaller than the mechanical spring constant k_{mech}.

In one implementation, the spring softening is used to tune the resonance frequency of the membrane **120**. For example, the resonance frequency of the membrane **120** is adjusted by changing the applied bias voltage, which effects spring softening. As shown in equation 10, the (free) resonance frequency is a function of the bias voltage V_{bias}:

$$f_0(V_{bias}) = \frac{1}{2\pi}\sqrt{\frac{k_{eff}}{M_{eff}}} = \frac{1}{2\pi}\sqrt{\frac{k_m + k_{el}(V_{bias})}{M_{eff}}} \tag{10}$$

In some implementations, the tuning bias voltage is applied to the tuning back-plate to facilitate the independent adjustment of the sensitivity of the membrane **120** (e.g., via the bias voltage applied thereto), and mitigate a need to adjust the bias voltage applied to the membrane to compensate for body noise. For example, the sensitivity of the membrane **120** is set to the desired level by selecting the bias voltage (thereby also setting the resonance frequency of the membrane), and then the tuning bias voltage applied to the tuning-back-plate **140** is selected responsive to the bias voltage applied to the membrane **130** to set the resonance frequency of the back-plate **130** to be substantially equal to the resonance frequency of the membrane **120**.

In another implementation, the tuning back-plate **140** is used to de-stick the membrane **120** from the back-plate **130**. During manufacturing of the MEMS microphone **100**, the membrane **120** can become stuck to the back-plate **130**. The application of the tuning bias voltage between the back-plate **130** and the tuning back-plate **140** electrostatically attracts the back-plate **130** to the tuning back-plate, thereby detaching the back-plate **130** from the membrane **120**.

FIG. **2** shows a diagram of a capacitive MEMS microphone **200**, according to another example embodiment of the present invention. The microphone **200** is similar to the microphone **100** of FIG. **1**. The microphone **200** includes a semiconductor substrate **210** having an opening **212** that extends through the substrate **210**. A membrane **220** extends across the opening **212** in the substrate **210**. A perforated back-plate **230** also extends across the opening **212** in the substrate **210**. The back-plate **230** is separated from the membrane **220** by insulating material **232**. The microphone **200** further includes a perforated tuning back-plate **240** that extends across the opening **212** in the substrate **210**. The tuning back-plate **240** is separated from the back-plate **230** by insulating material **242**. A back-chamber **250** encloses the opening **212** to form a pressure chamber with the membrane **220**. The back-chamber **250** encloses the opening **212** in the substrate on the opposite side of the substrate **250** from the back-chamber **150** of the microphone **100** in FIG. **1**.

A bias circuit **260** is configured to apply a bias voltage between the membrane **220** and the back-plate **230** to set the sensitively of the membrane **220**. The bias circuit **260** is also configured to apply a tuning bias voltage between the back-plate **230** and the tuning back-plate **240**. The application of the tuning bias voltage electrically tunes the resonance frequency of the back-plate **230** to match the resonance frequency of the membrane **220** and thereby suppress body noise without changing the sensitivity of the membrane **220**. In one implementation, application of the tuning bias voltage alters the resonance frequency of the back-plate **230** via electrostatic force between the tuning back-plate **240** and the back-plate **230**.

FIG. **3** shows a diagram of a capacitive MEMS microphone **300**, according to a further example embodiment of the present invention. The microphone **300** includes a semiconductor substrate **310** having an opening **312** that extends through the substrate **310**. A membrane **320** extends across the opening **312** in the substrate **310**. A perforated back-plate **330** also extends across the opening **312** in the substrate **310**. The back-plate **330** is separated from the membrane **320** by insulating material **332**. The microphone **300** further includes a back-chamber **350** that encloses the opening **312** to form a pressure chamber with the membrane **320**.

A bias circuit **360** is configured to apply a bias voltage between the membrane **320** and the back-plate **330** to set the sensitivity of the membrane **320**. The bias circuit **360** is also configured to apply a tuning bias voltage between the back-plate **330** and a wall of the back-chamber **350**. The application of the tuning bias voltage electrically tunes the resonance frequency of the back-plate **330** to match the resonance frequency of the membrane **320** and thereby suppress body noise without changing the sensitivity of the membrane **320**. For example, application of the bias voltage **352** alters the resonance frequency of the back-plate **330** via electrostatic force between the wall of the back-chamber **350** and the back-plate **330**.

FIG. **4** shows a schematic MEMS microphone **400** having a microphone body **410**, and a membrane **420** and a back-plate **430** that each have their own spring constant (k**1** and k**2**) and mass (m**1** and m**2**). The membrane **420** and the back-plate **430** each have a different sensitivity for acceleration (shown by the arrow in FIG. **4**). As a result, mechanical vibrations introduce body noise. The body noise resulting from mechanical vibrations is suppressed by matching the resonance frequency of the back-plate **430** to the resonance frequency of the membrane **420**. The mass spring-constant ratio M/k (see e.g., equation 3) determines the sensitivity and the resonance frequency of the membrane **420**, as well as the resonance frequency of the back-plate **430**. The application of the bias voltage between the membrane **420** and the back-plate **430** affects the spring constant k**2** of the membrane **420** and thereby adjusts the sensitivity and the resonance frequency of the membrane **420**. Thus, the bias voltage is used to set the sensitivity and the resonance frequency of the membrane **420**. A tuning bias voltage is applied between the back-plate **430** and a tuning back-plate (not shown in FIG. **4**). The tuning bias voltage affects the spring constant k**1** of the back-plate **430**, and thereby electrically tunes the resonance frequency of the back-plate **430**. Thus, the tuning bias voltage is used to set the resonance frequency of the back-plate **430** substantially equal to the resonance frequency of the membrane **420**, and thereby suppress body noise.

Accordingly, while the present invention has been described above and in the claims that follow, those skilled in the art will recognize that many changes may be made thereto without departing from the spirit and scope of the present invention.

What is claimed is:

1. A capacitive micro-electromechanical system (MEMS) microphone comprising:
- a semiconductor substrate having an opening that extends through the substrate;
- a membrane extending across the opening and configured to generate a signal in response to sound;
- a back-plate extending across the opening, the back-plate separated from the membrane by an insulator and exhibiting a spring constant;
- a back-chamber that encloses the opening to form a sealed pressure chamber with the membrane; and
- an electrical tuning structure including a tuning back-plate configured to set a resonance frequency of the back-plate in response to a first bias voltage applied to the tuning back-plate, wherein the electrical tuning structure is configured to
- apply the first bias voltage between the back-plate and the membrane to adjust a sensitivity of the membrane for responding to sound, and
- apply a second bias voltage between the tuning back-plate and the back-plate to control the tuning back-plate to set the resonance frequency of the back-plate independent of the sensitivity of the membrane, wherein the resonance frequency of the back-plate is set to a value that is substantially the same as a value of a resonance frequency of the membrane.

2. The MEMS microphone of claim **1**, wherein the MEMS microphone is subject to body noise, due to a difference between the resonance frequency of the membrane and the resonance frequency of the back-plate; and the tuning structure includes the second bias voltage is sufficient to change the resonance frequency of the back-plate to be substantially equal to the resonance frequency of the membrane, thereby mitigating the body noise.

3. The MEMS microphone of claim **2**, wherein: the membrane is subject to sticking to the back-plate; and the electrical tuning structure is configured to unstick the membrane from the back-plate by applying a bias voltage to the tuning back-plate, thereby detaching the back-plate from the membrane.

4. The MEMS microphone of claim **1**, wherein the tuning back-plate is arranged substantially parallel to the membrane and the back-plate and the back-plate is located between the membrane and the tuning back-plate.

5. The MEMS microphone of claim **4**, wherein the back-plate is perforated and spring suspended; and the second bias voltage applied between the tuning back-plate and the back-plate is based on the first bias voltage applied between the back-plate and the membrane.

6. The MEMS microphone of claim **1**, wherein the tuning structure includes the back-chamber, and the back-chamber is configured to adjust the resonance frequency of the back-plate responsive to a bias voltage applied between a wall of the back-chamber and the back-plate.

7. The MEMS microphone of claim **1**, wherein the tuning structure includes a tuning back-plate that is separated from the back-plate by another insulator and that exhibits a spring constant.

8. The MEMS microphone of claim **7**, wherein the tuning structure further includes a bias circuit configured to apply the second bias voltage to between the back-plate and the tuning back-plate.

9. The MEMS microphone of claim **7**, wherein the tuning back-plate is located a distance from the back-plate, the distance being such that electrostatic force resulting from application of the second bias voltage controls the resonance frequency of the back-plate.

10. The MEMS microphone of claim **1**, wherein the back-chamber is located on a surface of the substrate and the membrane is located between the back-plate and the back-chamber.

11. MEMS microphone of claim **1**, wherein the tuning structure is configured to match a mechanical acceleration response of the back-plate to a mechanical acceleration response of the membrane.

12. A capacitive micro-electromechanical system (MEMS) microphone comprising:
- a semiconductor substrate having an opening that extends through the substrate;
- a pressure sensitive membrane extending across the opening and configured to generate a signal in response to sound waves;
- a spring-suspended back-plate extending across the opening, the spring-suspended back-plate separated from the pressure sensitive membrane by a first insulator and exhibiting a spring constant;
- a tuning back-plate, the tuning back-plate extending across the opening and separated from the spring-suspended back-plate by a second insulator;
- a back-chamber that encloses the opening to form a sealed pressure chamber with the membrane; and
- a bias circuit configured to
- apply at least one bias voltage to the tuning back plate to set a resonance frequency of the spring-suspended back-plate, and
- wherein another bias voltage between the membrane and the spring-suspended back-plate causes the resonance frequency of the spring-suspended back-plate and the resonance frequency of the membrane to correspond to one another.

13. The MEMS microphone of claim **12**, wherein the bias circuit is further configured to set the frequency response of the membrane for responding to sound, and wherein the tuning bias voltage is based on the bias voltage applied between the spring-suspended back-plate and the membrane.

14. The MEMS microphone of claim **12**, wherein the tuning back-plate is configured to set the resonance frequency of the spring-suspended back-plate responsive to the other bias voltage by exhibiting an electrical force to influence the spring constant of the spring-suspended back-plate to set the resonance frequency of the spring-suspended back-plate and suppress introduction of body noise via the spring-suspended back-plate.

15. The MEMS microphone of claim **12**, wherein the tuning back-plate is stiffer than the spring-suspended back-plate.

16. The MEMS microphone of claim **12**, wherein the bias circuit configured to apply the other tuning bias voltage to the tuning back-plate to set an effective spring constant of the spring-suspended back-plate and thereby match a mechanical acceleration response of the back-plate to a mechanical acceleration response of the membrane.

17. method for suppressing introduction of body noise in a capacitive micro-electromechanical system (MEMS) microphone, the microphone including a semiconductor substrate having an opening that extends through the substrate, a membrane extending across the opening and configured to generate a signal in response to sound waves, a back-plate extending across the opening and separated from the membrane by a first insulator, a tuning back-plate extending across the opening and separated from the back-plate by a second insulator, and a back-chamber that encloses the opening to form a sealed pressure chamber with the membrane, the method comprising:

selecting a bias voltage to be applied between the membrane and the back-plate;

applying the bias voltage between the membrane and the back-plate to set a sensitivity of the membrane;

selecting a tuning bias voltage to be applied between the back-plate and the tuning back-plate; and

applying the tuning bias voltage between the back-plate and the tuning back-plate to set a resonance frequency of the back-plate and to suppress the introduction of body noise in the MEMS microphone.

18. The method of claim **17**, wherein applying the tuning bias voltage includes applying the bias to match a mechanical acceleration response of the back-plate to a mechanical acceleration response of the membrane.

19. The method of claim **18**, wherein the tuning bias voltage is selected responsive to the bias voltage applied between the membrane and the back-plate, and wherein applying the tuning bias voltage between the back-plate and the tuning back-plate sets the resonance frequency of the back-plate substantially equal to the resonance frequency of the membrane.

20. The method of claim **17**, wherein applying the tuning bias voltage between the back-plate and the tuning back-plate de-sticks the back-plate from the membrane.

21. The MEMS microphone of claim **1**, wherein the back-plate is located between the membrane and the back-chamber.

22. The MEMS microphone of claim **2**, wherein:

the back-plate is located between the membrane and the back-chamber; and

the tuning back-plate is located between the back-plate and the back-chamber.

23. The MEMS microphone of claim **2**, wherein:

the back-chamber is located on a surface of the substrate and the membrane is located between the back-plate and the back-chamber; and

the back-plate is located between the tuning back-plate and the membrane.

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